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A general purpose computer interface unit for electrical and electronics education

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Abstract

In this study, a multipurpose computer interface unit is designed for existing regular experiment sets of electrical and electronics laboratories which includes embedded two channels digital storage oscilloscope, multimeters, digital inputs and outputs, miscellaneous function generators, a variable and some fixed power supplies in order to experiment in a more comprehensive manner without any need of external measurement devices or signal supplies. All studies and observations including the lecture notes, experiment instructions, calculations and graphical reports are computer assisted by the use of interface software which also gives the opportunity to the instructor computer to track and control the student computers over the network. This paper includes the observation of the related studies and final results in detail.

Keywords: Electrical and electronics education; computer based interface unit; measurement devices; signal supplies.

1. Introduction

For a basic experiment in the frame of electrical and electronics study, it is required to use an oscilloscope for displaying signals, a multimeter for measuring electric circuit quantities such as current, voltage, resistance, etc. and signal generators, power supplies for miscellaneous applications. Due to the cost of these hardware and difficulties in the usage of all these devices together, computer assisted educational training sets became promising in the market in the last few years.

Laboratory setups[1], which is created to learn interface between system modules by students, numeric signal processing, power electronics and using of web-based education tools in education for electrical circuit theory education[2-4], voltage stability toolbox[5], various simulations for electrical-electronics education[5-8] and computer supported various experiment setups[9-10], are all present, however limited solutions for technical education.

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Figure 1. General view of V-LAB Computer Interface Unit

In this work, a multipurpose computer interface unit called V-LAB with a general view seen in Figure 1, is designed as a combined solution for experiments in electrical-electronics and physics courses. This interface unit includes embedded two channels digital storage oscilloscope, multimeters, digital inputs and outputs, miscellaneous function generators, a variable and some fixed power supplies in order to work with existing regular experiment sets of electrical and electronics laboratories in a more comprehensive manner without any need of external measurement devices or signal supplies. USB communication is used for bidirectional data transfer between computer and the V-LAB while the computer screen is used for displaying all measurements visually, graphically or numerically and keyboard or mouse for controlling signal generators, adjustable power supplies, output units or any other settings. Also V-LAB is capable of generating up to 8 faults for experiment modules that are designed with suitable connections for this computer interface unit. All measurement and supply devices are designed visually identical as their bench top versions in order to make students familiar with all these devices by the end of their education. All studies and observations including the lecture notes, experiment instructions, calculations and graphical reports are computer assisted by the use of interface software which also gives the opportunity to the instructor computer to track and control the student computers over the network.

In the second part of this article, hardware will be examined in detail; software overview will follow as the third part, and the final results and benefits will be presented as a conclusion.

2. Hardware of the Interface Unit

Hardware that has the block diagram in Figure 2, divides into two main groups according to the operating frequencies of the devices included. These are oscilloscope, pulse generator, arbitrary waveform generator that constitute the high frequency group and multimeters, variable DC supply, relays and digital input-outputs that constitute the low frequency group. The PIC18F4550 microcontroller is the main controller of the system which operates at 48MHz while Xilinx Spartan-3E FPGA is managing the high frequency group at 100 MHz operating frequency under the control of PIC18F4550.

System includes a main and a daughter board default but it is possible to increase the number of daughter boards in order to increase the number of devices included to V-LAB. The main controller of the system and the high frequency group devices are placed on the main board. I2C serial communication is used for interfacing between main microcontroller and the sub microcontroller PIC16F877A which generates the control signals for the daughter board. I2C is used also for communicating with several integrated circuits places on both main and daughter boards and with some integrated circuits on the main board. The main controller is also used for USB communication with the computer.

The USB communication between hardware and software is based on MODBUS protocol and system architecture is designed register based. By the USB communication data is transferring to system registers which are distributed between main and sub microcontrollers, FPGA and some integrated circuits. The main controller accepts the data for system registers related with itself or redirect the data in parallel to FPGA or serially to sub controller and other related integrated circuits simultaneously. The system operates according to the data written in the registers and the control signals that are generated by the related controller.

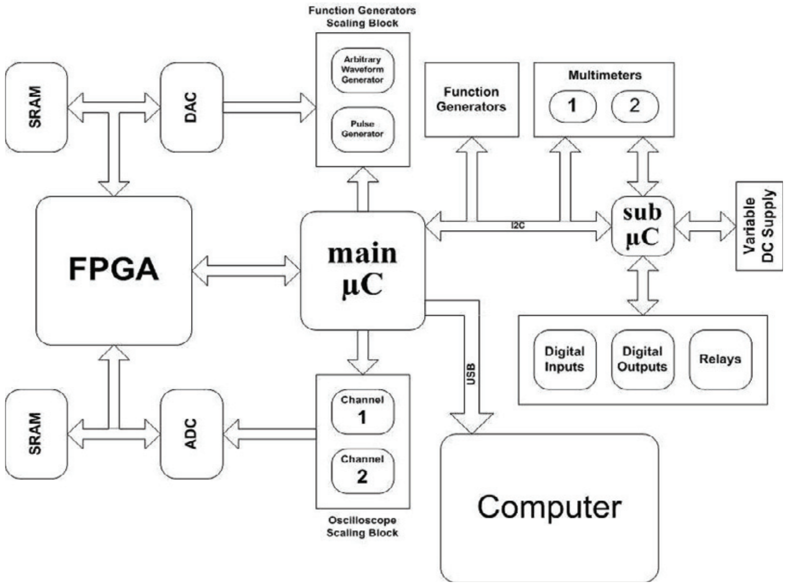

Figure 2. Hardware Block Diagram

In the frame of high frequency group studies, a highly efficient memory mapping structure is designed and by the implementation of hardware triggering structure for oscilloscope on the FPGA, effective usage of memory block is established. The usage of reverse structure of developed oscilloscope architecture, a 128k point arbitrary waveform generator is designed. Also a pulse generator with 1% PWM accuracy is implemented on FPGA.

The low frequency group devices are designed to operate standalone in order not to make main controller busy to prevent any decrease in the system communication speed. The inputs and outputs of these devices are stored in internal block registers or sub controller registers. The main controller collects these data by I2C and transfers them to the computer via USB in a time schedule that provides robustness to the system.

Designed computer interface unit V-LAB includes the devices with the listed specifications on the Table 1.

Table 1. Embedded Devices, Specifications, Features

Device	Specification	Features
Oscilloscope	2 Channels, 4 MHz, 8 Mb	signal storage, spectrum analyzing
Multimeter	2 units Voltage / Ampere Resistance / Capacitance	DC / AC (true RMS), expansion available
Function Generator	0,5Hz-1MHz, 20Vpp	expansion available
Arbitrary Waveform Generator	1Hz-1MHz, 20Vpp	computer aided waveform design available
Pulse Generator	1Hz-1MHz, 20Vpp	1% PWM
Variable DC Supply	0-30V, 1A	current limitation, expansion available
Fixed DC Supply	-5V / 0V / +5V, 1A -12V / 0V / +12V, 1A	Isolated, expansion available
Fixed AC Supply	2 units 12V RMS, 50Hz, 1A	Isolated, expansion available
Digital I/O	16 inputs, 16 outputs 32 units total	expansion available
Relays / Fault Generation	8 units	expansion available
Computer Interface	USB 2.0	Full Speed

3. Software of the Interface Unit

Developed softwares for the interface unit can be overviewed in three main titles. These are embedded softwares as a part of hardware, communication and device softwares which support the hardware and the experiment platform software which brings the opportunity of computer adaptive education.

Embedded softwares includes communication protocol, general register based structure and the control of the system which are developed for PIC microcontrollers by C compilers of Microchip and CCS. Also some required hardware blocks are implemented for Xilinx FPGA by Xilinx ISE software. These hardware blocks that are designed by the use of VHDL are oscilloscope module, arbitrary waveform generator module, pulse generator module and several frequency dividers and counters that are required for these modules.

On the other hand, device softwares are graphically designed similar with real bench top devices by Microsoft Visual Studio .NET. As it can be seen from Figure 3, users can easily use the software as a real bench top oscilloscope through the oscilloscope window. Also, students will be introduced to special devices like the arbitrary function generator in Figure 4 in a cost-efficient way. The main and the most important block for this group software is the hardware interfacing protocol which has an algorithm as shown in Figure 5.

As the last group of software which may be the most important tool for the device as an educational interface unit is V-LAB experiment platform. This platform includes three scroll-down menus which are devices, lecture notes and experiments as it can be seen in Figure 6. Students should login to the network by the acceptance of the instructor's computer, so that the experiment is enabled to be tracked by the instructor, and the reports can be submitted by students.

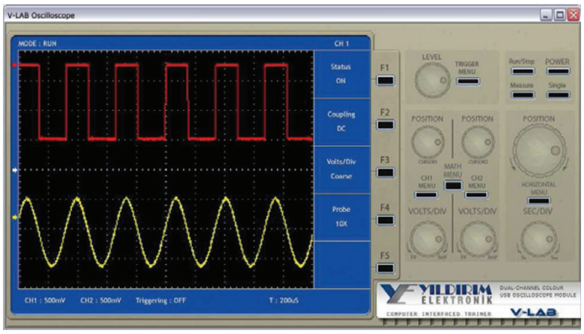

Figure 3. Oscilloscope Window

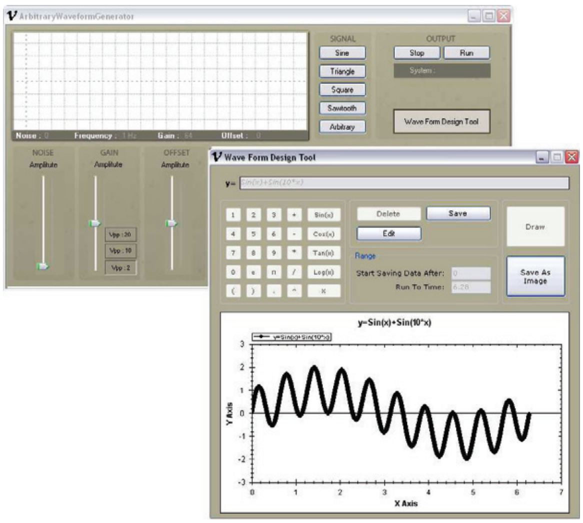

Figure 4. Arbitrary Waveform Generator Window

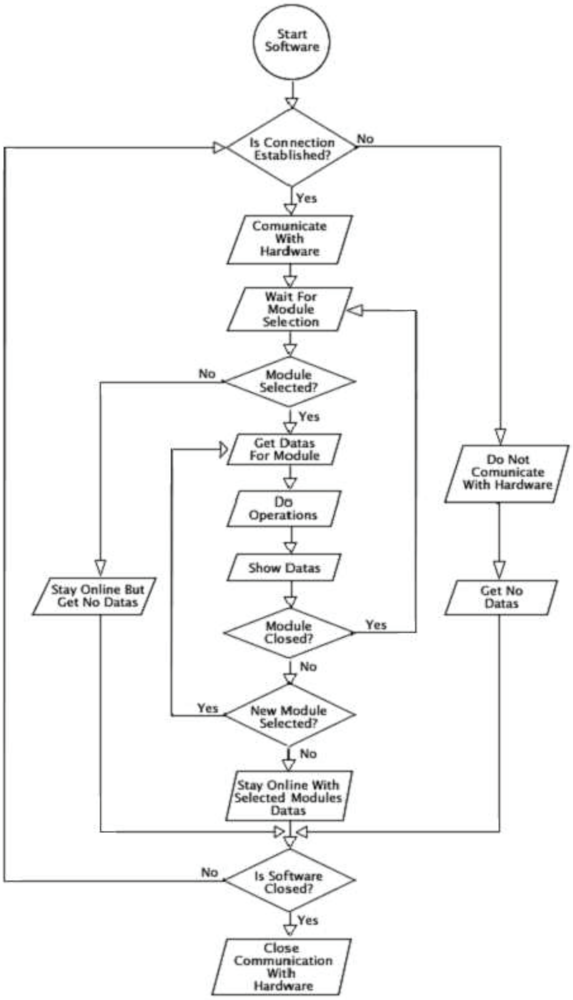

Figure 5. Hardware Interfacing Protocol Algorithm

Figure 6. V-LAB Experiment Platform Window

Figure 7. A demonstration performed using V-LAB with an experiment module of Yildirim Elektronik

4. Conclusion

Laboratory practices carry an extremely important role in technical education. As there are various needs according to the intention of the experimental work, the embedded oscilloscope, multimeters, function generators, variable dc supply, digital inputs and outputs of this interface unit will fulfill the needs.

Alongside the fulfillment of these needs, the costs of building up a laboratory will decrease, the area needed for the working space will decrease, and a more functional experimentation area will be provided. The actual visuals of the devices that are generated on the computer screen will help students to become familiar with real devices by the use of V-LAB. This developed interface unit provides a huge variety of extended experimentation for electric-electronic scholars, with the variety and capacity of embedded devices.

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